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Do best manufacturing practices depend on the plant role in international manufacturing networks?

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Abstract
In the last decades several companies have become manufacturing networks of plants, usually in an international context. These plants can serve different purposes and have different level of competences. This diversity has to affect the use and pay off of various operations management practices. This paper investigates the relationship between plant roles and the "goodness" of manufacturing practices using the International Manufacturing Strategy Survey. According to our results plants with higher competence (leaders and contributors) have more best practices than less competent plants. Servers can build their competences through interplant networking activities, while offshore plants utilize servitization to improve performance.

Keywords: Manufacturing practices, plant role, manufacturing network, performance

Introduction
Several papers in the literature argue that international manufacturing networks (IMNs) operate all over the world with different manufacturing plants playing different roles within the network. There is also an impressive body of literature about the use of manufacturing practices in single plants and their impact on performance, referring to the most effective ones as best practices. The question addressed in the paper is whether the "goodness" of manufacturing practices depends on the role a plant plays in an IMN.

Since Ferdows' seminal article (1997) on plant roles, many papers have been published on this topic. As Ferdows argues, sites can improve their competences by building up knowledge not only in the field of production, but also in purchasing, distribution, customer relationships, and innovation, thereby developing themselves toward "higher" roles. Although Ferdows' original article contains only examples, several papers operationalized his work through case studies (Vereecke and Van Dierdonck, 2002; Miltenburg, 2009; Cheng, 2011; Cheng et al., 2011) and surveys (Feldmann et al., 2009; Turkulainen and Blomqvist, 2011), and basically found the framework to be valid. What these papers did not do, however, is look at the manufacturing practices these plants use and their performance outcomes.

Furthermore, there are some papers that explore the impact of national context on the use of manufacturing practices (e.g. Cagliano et al., 2001; Vastag and Whybark, 1991; Oliver et al., 1996; Voss and Blackmon, 1996). However, none of them investigates the impact of the role these plants play within their IMNs. Following these two observations we investigate the extent to which plant role affects the goodness of various manufacturing practices in terms of their performance implications. First we go through the literature. Then we introduce the database and the research methodology. We analyze data and discuss our findings. Finally we draw some preliminary conclusions.

Literature review

Both plant roles and best practices have been extensively researched in the last decades.

Ferdows (1997) was the first to develop a typology going more deeply into value creating activities within plants and using the perspective of plants instead of the whole network. He identified three strategic reasons for choosing a specific site: a) access to low-cost production, b) access to skills and knowledge, and c) proximity to market. Vereecke and Van Dierdonck (2002) identified nine potential strategic reasons from the literature, but exploring an interview-based sample of 59 companies they concluded that the main location drivers identified by Ferdows (1997) are by far the most important ones.

Ferdows (1997) determined the level of site competence as well. Along the strategic reasons and site competences, plants can position themselves in six different roles (the list in Table 1 is ordered from lowest to highest level of competences). As Ferdows argues, sites can improve their competences, especially by building up knowledge not only in the field of production, but also in purchasing, distribution, customer relationships (altogether in SCM), and product/process development, thereby developing themselves toward "higher" roles. Competence development and roles depend on managerial aspirations as well as on country level factors. Ferdows does not define a strict relationship between strategic reasons and competences.

Competences were in the center of analysis in Feldmann et al. (2013). They found three basic bundles of competences that plants can develop: a) *production competence*, including process improvement, technical maintenance and production, b) *supply chain competence* containing supplier development, procurement and logistics, and c) *development competence* consisting of introduction of new product technologies, product improvement and introduction of new process technologies. Plant competences are cumulative: plants with supply chain competences already have production competence, and development competence is built on production and supply chain competence.

Turkulainen and Blomqvist (2011) also identified three clusters of 101 Finnish companies based on their level of competences. They used two additional competences compared to Feldmann et al. (2013): production planning and supplying global markets. Based on factor analysis of potential competences they identified a forth competences bundle as compared to Feldmann et al. (2013) by splitting production competence into process and manufacturing competences. The former contains process improvement and technical maintenance, while the latter incorporates production planning beside production. Process and production competence values are very similar in each cluster, so their separation does not add too much value. Supplying global markets belongs to the development competence bundle. Both Vereecke and Van Dierdonck (2002) and Turkulainen and Blomqvist (2011) mention that even if some plants were established in order to serve markets (contributors), through time they became a hub of knowledge, practically reaching the competence level of leader plants.

Based on these findings we can build an intuitive relationship between plant roles, their purposes and competences as described in Table 1.

Table 1 – Plant roles, strategic reasons and competences

Plant roles	Strategic reason	Competences
Outpost	Access to skills and knowledge	Limited production competence
Offshore	Access to low cost production	Production competence
Server	Proximity to market	Production and limited SCM competences
Source	Access to low cost production	Production and SCM competences
Contributor	Proximity to market	Production, SCM and (limited) development competences
Leader	Access to skills and knowledge	Hub for product/process knowledge

Source: based on Ferdows , 1997; Vereecke and Van Dierdonck, 2002;Turkulainen and Blomqvist 2011; and Feldman et al., 2013;

According to Voss (1995) best practices are one of the alternative paradigms of manufacturing strategy. "The underlying assumption of this paradigm is that best (world class) practice will lead to superior performance and capability. This in turn will lead to increased competitiveness" (Voss, 1995:10). Laugen et al. (2005) suggest that best practices are what the best performing companies do, that is, companies with the best performance improvement results. Davies and Kochhar (2002) also suggest that best practices are those leading to significant improvement of performance.

Best practices change over time and are context dependent. Using an international survey Laugen et al. (2005) found that quality management and ICT lost their best practice status in early 2000 to lean management techniques such as process focus, pull production and equipment productivity, plus environmental compatibility. They also indicated e-business, new product development, supplier strategy and outsourcing as potential best practices in the future. And indeed, some years later Laugen et al. (2011) identified four best practices: lean manufacturing, supply chain management, new product development and servitization. Boer et al. (2013) analyzed if these four bundles are best practices everywhere looking at home and host country effects. They concluded that, while lean manufacturing, supply chain management and servitization are best practices in plants where country of origin and country of location are at the same level of development (both countries are either more developed or less developed), new product development is a best practice only in plants where a parent company from a more developed country established a plant in a less developed one.

Laugen et al. (2011) controlled for company size and production process type, Boer et al. (2013) for country context, but none of them for plant type. Thus, it is not clear if the practices identified above are best for all types of plants.

Consequently, due to the diversity of roles a manufacturing plant can play in a manufacturing network, we propose that best practices can also depend on the role that plants fulfill. Since plant role depends on competences, we can expect that higher competences imply the implementation of more practices more successfully, resulting in higher performance improvement.

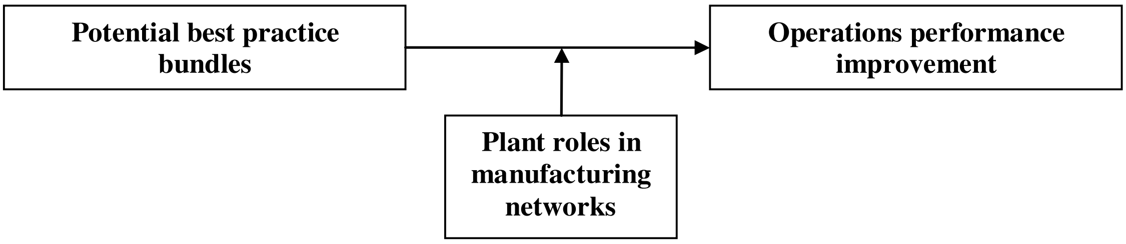

Figure 1 – The research framework

Research methodology

Research sample

Plant roles within IMNs, as well as manufacturing practices and performance are measured using data from the sixth round of the International Manufacturing Strategy Survey (IMSS VI). The IMSS is carried out by an international network of researchers focusing on the manufacturing strategies, practices and performances of manufacturing plants from all around the world (www.manufacturingstrategy.net). IMSS VI was carried out in 2013 and currently includes responses from 19 different countries (some more countries are still expected to contribute with their data). The data collection process was administered in each country by local coordinators. Wherever needed, English language questionnaires were translated into local language by manufacturing strategy academics using a reliable method (double and/or reverse translation). Targeted plants were chosen from official databases of manufacturing organizations in each country, belonging to the ISIC Rev. 4 Divisions 28-35 (manufacture of fabricated metal products, machinery and equipment). The questionnaire was filled in by Manufacturing/Operations Managers. The unit of analysis is the manufacturing plant, also including some business unit level data on competitive position. In its current version the IMSS VI database contains data collected from 843 manufacturing plants. Despite the large overall sample size an important drawback of the data employed is that individual country samples are not statistically representative. However, the relatively high number of respondents and the diversity of countries enabled us to search for general relationships and tendencies connected to manufacturing plants in an international context.

To define our research sample, we first selected manufacturing plants that are members of a manufacturing network consisting of multiple plants within the same company. The IMSS VI questionnaire enquired about whether the manufacturing plant is a stand-alone plant (being the only plant that belongs to the company) or part of a domestic, regional or global manufacturing network. Altogether 534 plants were identified as manufacturing network members, which represents 63.3% of the total sample.

Measurement

To identify best practice bundles and performance improvement indicators exploratory factor analysis (EFA) was used with principal components extraction and VARIMAX rotation.

The IMSS VI questionnaire enquired about the effort put in the last three years into implementing 61 different action programs connected to manufacturing and supply chain operations (1-5 Likert scale: 1="None", 5="High"). Using EFA the multitude of action programs was reduced to 11 factors, i.e. bundles of manufacturing practices. The resulting practice bundles are: responsibility and quality, human resource management, technology improvement, internal integration, customer integration, supplier integration, networking, risk management, product development, servitization, and lean production. The components of each factor, as well as factorability and reliability measures are presented in Appendix 1.

In respect of performance indicators the IMSS VI questionnaire asked respondents to indicate how their manufacturing performance has changed over the last three years on 18 operational performance indicators. Performance improvement was measured on a 5-point scale: 1="Decrease (-5% or worse)", 2= "Stayed about the same (-5%/+5%)", 3= "Slightly increased (+5/+15%)", 4= "Increased (+15/+25%)", 5= "Strongly increased (+25% or better)". For items where lower values represent better values (e.g. cost, lead time, pollution emission) a reverse scale was used. Factor analysis resulted in altogether three groups of performance improvement indicators: differentiation performance, cost performance, and green performance. The first two factors follow the logic of Porter's (1985) two main sources of competitive advantage (differentiation and cost), while the third one emerges as a relatively new performance indicator (de Burgos Jimenez and Cespedes Lorente, 2001). Details are presented in Appendix 2.

To identify different plant roles within manufacturing networks, two variables were used: 1) respondents were asked to indicate on a 1-5 Likert scale to what extent their plant is responsible for production, supply chain, or development, or is a hub for product/process knowledge (1= "No responsibility", 5= "Full responsibility"); 2) respondents also had to indicate to what extent the following advantages apply to the location of their plant: access to low cost resources, proximity to market, and access to knowledge and skills (1= "Strongly disagree", 5= "Strongly agree"). The first variable is derived from the work of Feldman et al. (2013), Vereecke and Van Dierdonck (2002), and Turkulainen and Blomqvist (2011). The second variable corresponds to the possible advantages identified by Ferdows (1997). Using hierarchical cluster analysis with Ward's method, and subsequent k-means cluster analyses, the following four plant types (Ferdows, 1997) were identified in our sample: 1) Leader (N=129), 2) Contributor (N=183), 3) Server (N=89), 4) Offshore (N=107). The values of the two clustering variables for each cluster are shown in Figure 2.

The first two clusters (red and blue line in Figure 2) have clearly higher competences than the other two clusters. Although the biggest difference between them is in low cost motivation, for the blue cluster proximity to markets and access to skills and knowledge are equally important, scoring highest on the proximity factor. Therefore, this cluster was termed, based on the literature, "Contributor". The other highly competent group (red line) has clearly the highest competencies and is particularly focusing on access to skills and knowledge, corresponding to the image of a hub for company know-how. Thus, this cluster was termed "Leader".

The two other clusters have lower competencies. The main difference is that the purple cluster (Figure 2) concentrates solely on production, and has far more advantages from low cost production, which altogether point towards the characteristics of an "Offshore" plant. The cluster marked with green line has rather high competences not only in production, but to some extent in supply chain management as well. Low cost reasons do not play an important role, contrary to the proximity to markets factor, which altogether point towards the characteristics of a "Server" plant.

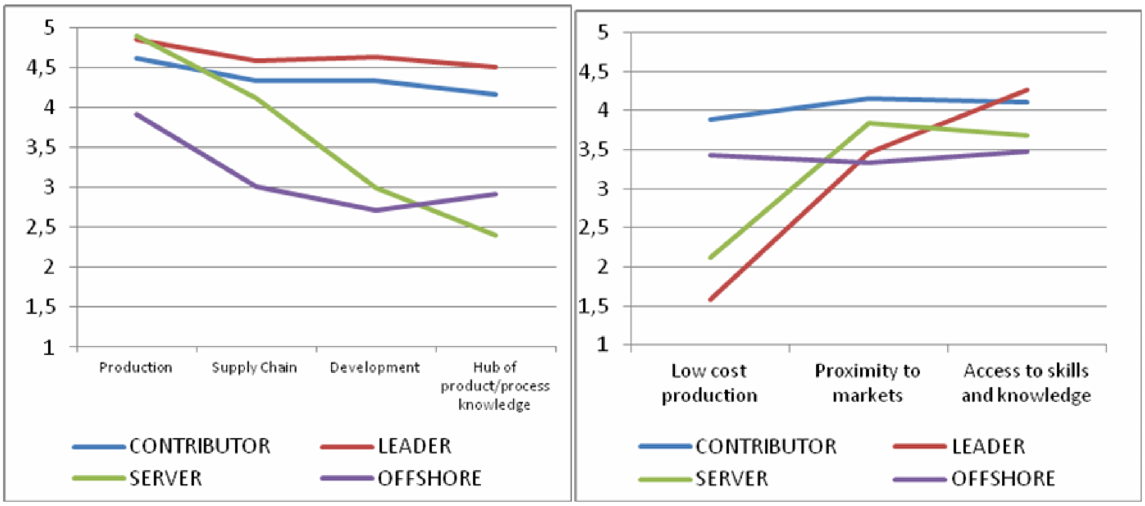

Figure 2 – Competences (left) and strategic reasons (right) of plant types clusters

Preliminary findings and discussion

Using the clusters and variables developed separate multiple regression analyses were carried out for each cluster and each performance factor, with bundles of different manufacturing practices as predictor variables. Additionally, to check which practice bundles can be considered best practices on an aggregate level, another regression analysis has been run on the total sample containing all four plant types. The results are summarized in Table 2.

On a general level (denoted OVERALL in Table 2), customer integration and servitization seem to be the most evident best practices (with significantly positive impact on two performance indicators), followed by responsibility and quality, human resource management, and lean production. Technology development has a complex impact on performance, since it positively affects differentiation at a general level, but in case of some plant roles it has a negative effect on cost and green performance. It is also surprising that supplier integration has a negative effect on differentiation performance. Looking at different plant types, the best practices show a more differentiated picture.

Leader plants use responsibility and quality, human resource management and customer integration as best practices, which is in line with their role of being a hub for product/process knowledge (Table 2). Technology development, on the other hand, seems to have a negative influence on cost performance, which can be explained by the high investment and operating costs needed to implement and maintain new technologies in production. This result can also be explained by the time lag. At the beginning, investments are costly, but they usually pay off on the long run. In our survey, performance is measured at the time when the investment was made.

Contributor plants use human resource management, technology development and servitization in order to successfully differentiate themselves from competition. (Table 2) Supplier integration, on the other hand, has a negative impact on differentiation performance. Since these highly competent plants are usually foreign subsidiaries in their host countries (they are placed close to their market by definition), they invest to nurture their suppliers, which is a long-term investment. Like the leader plants, contributor plants benefit from responsibility and quality practices to improve their “green” performance.

Table 2 – Results of the multiple regression analyses

Performance Practices	Differentiation performance	Cost performance	“Green” performance
Responsibility and quality	-	-	OVERALL*** Contributor** Leader* Server*
Human resource management	OVERALL*** Contributor** Leader*	Leader**	-
Technology development	OVERALL* Contributor**	*- Leader****	*- Server**
Internal integration	-	-	-
Customer integration	OVERALL*** Leader**		OVERALL** Leader***
Supplier integration	*- OVERALL**** *- Contributor **	-	-
Networking	Server*		
Risk management	-	-	-
Product development	-	-	-
Servitization	OVERALL*** Contributor* Offshore*	OVERALL**	Server**
Lean production	-	-	OVERALL** Server*

Server plants use networking as best practice to reach high differentiation performance improvement, which is not surprising considering that these plants need to develop their competences (by learning from others) in order to reach higher plant roles. Beside the negative impact of (the probably not environmentally friendly) technology, server plants use many different practices to increase their green performance: responsibility and quality, servitization and lean production.

Offshore plants appear to have few best practices, as their role is to supply the network with low cost products. Servitization seems to be the only means to differentiate themselves to some extent from competition, i.e. by not just producing at the lowest possible cost, but offering services as well alongside its products.

Altogether, at more competent plants (leader and contributor) more operations management practices pay off, partly because they probably use more of them, and partly because they implement practices more professionally. This professionalism is supported by the heavy use of human resource management practices, which can lead to learning organizations and the utilization of employee intelligence. Server plants seem to pay particular attention to green performance when implementing various practices. Offshore plants have the most limited toolbox to improve their performance.

Conclusion

Using a wider range of countries, industries, and manufacturing practices compared to previous studies, the preliminary findings of this research reveal that the "goodness" of manufacturing practices depends on plant role.

The picture emerging from the analysis presented in this paper is that the more competent leader and contributor plants successfully use a wider set of operations management practices than the less competent server and offshore plants. Differentiation and "green" are the hot performance areas, and the more competent plants tend to use different practices to affect these performance criteria.

Practices that are best for one type of plant are not necessarily best (e.g. human resource management, networking), and may actually have negative effects (e.g. technology development), for some or all the other types. Most practices affect one performance indicator; only two practices, notably human resource management and customer integration affect two of the three performance indicators – in both cases this concerns the leaders' performance. Most of the findings reported above are consistent with the nature of the types of plants distinguished in this paper.

Finally, internal integration, risk management and product development do not emerge as best practices for any of the four plant types. This may be due to the relative maturity of internal integration, the nature of risk management, and the fact companies have only recently started to offshore product development operations.

Further research will include manufacturing plant level data from countries not yet included in the IMSS VI database. Furthermore, there are some limitations worth considering for further research. First, we did not control for some important variables, such as company size or country. Second, due to the cross-sectional nature of our survey, the long term impact of some practice implementations cannot be followed, even if the long-term positive impact of some practices can be far beyond the short term negative implications. Further research, probably using a longitudinal dataset is needed to reveal these long-term implications. Such a dataset would also help identify whether there is one best trajectory for developing a plant to a higher competence level or if any trajectory will do.

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Appendix 1 – Bundles of manufacturing practices

Factor/variables	Factor loading	Factor/variables	Factor loading
Responsibility and quality (α=.923)		**Customer integration (α=.862)**	
Environmental certifications	.735	Sharing information with customers	.718
Social certifications	.707	Developing collaborative approaches with key customers	.734
Formal sustainability oriented communication, training programs	.738	System coupling with customers	.696
Energy/water consumption reduction	.671	Joint decision making with customers	.651
Pollution emission reduction and waste recycling programs	.698	System coupling with key suppliers	.481
Health and safety management	.657	**Networking (α=.857)**	
Work/life balance policies	.528	Information sharing in the network	.753
Suppliers' sustainability performance assessment	.480	Joint decision making in network	.708
Training/education in sustainability issues for suppliers' personnel	.461	Innovation sharing in the network	.636
Joint efforts with suppliers to improve their sustainability	.460	Communication with other plants	.724

Improving equipment availability	.442	Network performance management	.640
Benchmarking/self-assessment	.448	**Risk management (α=.843)**	
Human resource management (α=.830)		Preventing operations risks	.690
Delegation and knowledge	.656	Detecting operations risks	.699
Open communication between workers and managers	.665	Responding to operations risks	.666
Lean organization	.669	Recovering from operations risks	.648
Continuous improvement programs	.581	**Product development (α=.859)**	
Autonomous teams	.554	Design integration	.464
Workers flexibility	.717	Organizational integration	.401
Technology development (α=.802)		Technological integration	.435
Use of advanced processes	.700	Integrating tools and techniques	.450
"The factory of the future"	.650	Communication technologies	.564
Process automation programs	.586	Forms of process standardization	.648
Increasing information integration	.405	**Servitization (α=.770)**	
Product/part tracking and tracing	.550	Expanding the service offering	.810
Internal integration (α=.872)		Developing the skills needed for services	.766
Sharing information with purchasing department	.793	Designing products so that the after sales service is easier to manage/offer	.600
Joint decision making with purchasing department	.743	**Lean production (α=.725)**	
Sharing information with sales department	.749	Process focus and streamlining	.707
Joint decision making with sales department	.762	Implementing pull production	.597
Supplier integration (α=.815)			
Sharing information with suppliers	.600		
Developing collaborative approaches with key suppliers	.562		
Joint decision making with suppliers	.564		
International sourcing strategy	.401		

KMO =.943, Bartlett's test $\chi^2(1830)=13701.35$ *with p<.001, factor loadings>.40, TVE=63.14% by 11 factors*

Appendix 2 – Factors of performance improvement

Factor/variables	Factor loading	Factor/variables	Factor loading
Differentiation performance (α=.898)		**Cost performance (α=.752)**	
Quality and reliability	.718	Unit manufacturing cost	.803
Product assistance/support	.714	Manufacturing lead time	.757
Delivery reliability	.712	Ordering costs	.712
Delivery speed	.697	Procurement lead time	.619
New product introduction	.678	**Green performance (α=.733)**	
Customer service quality	.657	Pollution/waste production	.708
Conformance quality	.654	Materials/water/energy cons	.691
Customization	.648		
Workers motivation/satisfaction	.646		
Volume flexibility	.634		
Mix flexibility	.618		
Health and safety	.615		

KMO =.897, Bartlett's test $\chi^2(153)=5459.7$ *with p<.001, factor loadings>.60, TVE=55.66% by 3 factors*